Journal of mathematics and computer Science 7 (2013) 73 - 79

Contents list available at JMCS

Journal of Mathematics and Computer Science

Journal Homepage: www.tjmcs.com

Improving the Health Care Systems Performance by Simulation Optimization

Hamid Reza Feili[1]
Faculty of Engineering, Department of Industrial Engineering, Islamic Azad University of Karaj, Iran,
Hrfeili@gmail.com

Article history:
Received February 2013
Accepted March 2013
Available online April 2013

Abstract

Studying and improving health care services levels are considered as an essential issue in urban management systems and also crisis management. In such areas, detecting effective factors, managing the relationships, control of costs, defining and planning for health care services resources are significance. In current paper, by analyzing the patients' behavior in one hospital unit, development and optimization of the mentioned unit's performance and defining the optimum resources have been studied. In order to modeling of the study, simulation software ExtendSim has been used. By implementing the outcome of the study and optimization of the hospital resources, waiting time for the patients could be reduced significantly, and also the related costs can be controlled properly.

Keywords: Simulation, Optimization, Simulation Optimization, Emergency Simulation, Health Care Systems.

1. Introduction

Emergency departments across the nation are overcrowded. The number of emergency departments is decreasing, while patient volume is rising. Busy healthcare systems constantly provide new challenges to their managers and decision-makers due to high demands for service, high costs, limited budget, and healthcare resources. As a result, decision-makers are continuously studying efficacy and efficiency of existing healthcare systems, and must be able to evaluate the outcomes of any changes they make to these systems. Discrete-event simulation has become an effective tool for decision making to seek optimal allocations of resources to improve system performance. It has been widely used in manufacturing and other industries. Recently, due to the rapid development in computer technology, the functions of discrete-event simulation tools have been enhanced and extended. The simulation modeling of complex facilities and sophisticated logics have become feasible. Therefore, there has been an increasing trend of using simulation tools in health care to improve operations (see recent review by Jacobson and colleagues). This process enhances patient flow and reduces health care delivery costs. It also increases quality of service and patient satisfaction. Using such approach in this paper, we use simulation and optimization techniques to determine the best allocation of resources in Shariati emergency.

---

[1]Corresponding author

Over the last decade, there have been fruitful efforts in developing Simulation/optimization models for solving healthcare management problems. Côte (1999), Swisher et al. (2001), Blasak et al. (2003), and Sinreich and Marmor (2005) use simulation models to reproduce the behavior of a healthcare system in order to evaluate its performance and analyze the outcome of different scenarios. In these studies, the main objectives are to show decision-makers a realistic reproduction of the healthcare system at work. Optimization techniques have also been used as solution methods for healthcare management problems. Beaulieu et al. (2000) use a mathematical programming approach for scheduling doctors in the emergency room. Flessa (2000) uses a linear programming approach for the optimal allocation of healthcare resources in developing countries. De Angelis et al. (2003) present a methodology that interactively uses system simulation, estimation of target function and optimization to calculate and validate the optimal configuration of servers in a transfusion center. Instead of using mathematical models that attempt to explicitly represent the functioning of the system, resulting in large linear and integer models with many variables and constraints, De Angelis et al. (2003) adopt a simpler model, where the complexity is captured by a non-linear function estimated from simulated data. Baesler and Seplveda (2001) present a multi-objective simulation optimization model for a cancer treatment center. Baesler et al. (2003) present a simulation model combined with a design of experiments for estimating maximum capacity in an emergency room.

2. System Description

The flowchart of process is given in Fig1. The Entry patient first is checked up in triage. Then according to his situation, four different manners can be supposed for next stage:

1- 40% of entries are suspected to have fracture symptoms and therefore need to take a photo in the "Radiology".
2- 25% of entries are hear patients. In this case the doctor ordered for the person taking ECG acts. If the present patient is serious, he immediately transferred to the CCU that this section is out of the field of study in the emergency department in this article.
3- In 25% of cases, the affected person will be sent to "internal exam" for more examination.
4- 10% of entered patients don't place in these three categories and can be called Category IV. These patients, without doing any more actions in emergency department, are sent to other parts of hospital.

The trend of each of these patients in emergency departments is shown in Figure 1.

1-First mode patients:

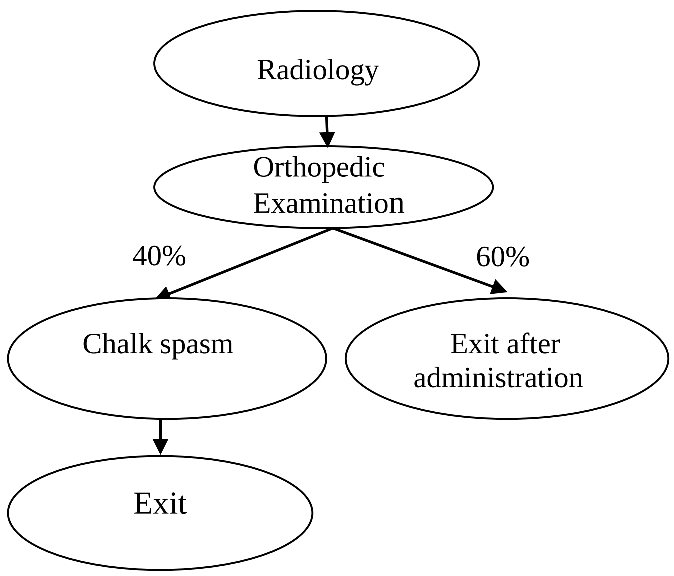

Figure 1. Flow process of 1st mode patients

2- Second mode patients:

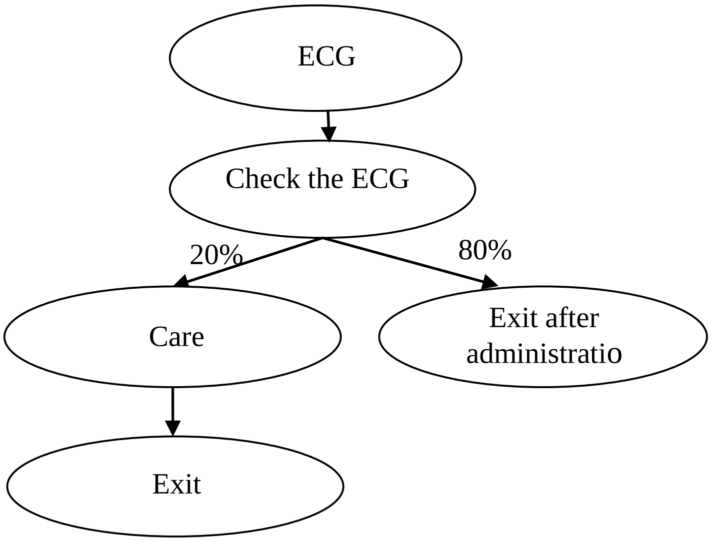

Figure 2. Flow process of 2nd mode patients

3- Third mode patients:

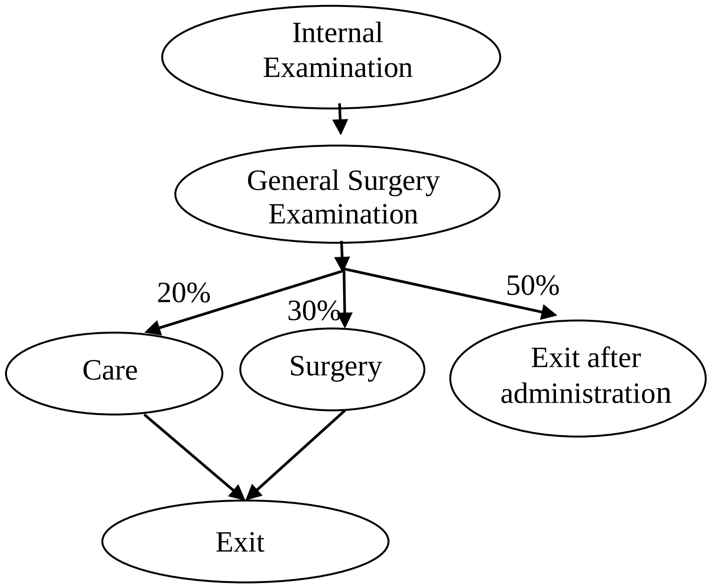

Figure 3. Flow process of 3rd mode patients

3. Data Collection

Data is collected during three days in the same hours (11-14) and flow process of 94 patients was recorded. However, to achieve acceptable levels of provision we should have different hours for collecting data in which there are significant differences in arrival times so in distribution functions.

The collected data about arrival time is shown in Table1.

Table1. Arrival times

Xi	Fi	Xi	Fi
1	6	7	4
2	13	8	3
3	19	9	3
4	21	10	1
4	15	11	1
6	7	12	1

The collected data about service time is shown in Table2. The time is given in minutes.

Table2. Service times

Activity	Minimum	Most probable	Maximum
Primary Examination in Triage	2	4	7
Radiology	7	9	13
Orthopedic Examination	3	3	6
Chalk spasm	22	26	33
ECG	10	15	20
Check the ECG	4	5	7
Internal Examination	5	8	14
General Surgery Examination	8	11	17
General Surgery	10	30	50
Care	120	600	2160

4. Input Definition

1. Entries: To define the entries according to arrival times the Generator block should be used. So we enter the collected data in “Empirical table” and click on “Interpolated” icon to show that the real amounts between discrete amounts can be created also.
2. To define activities there are two types of blocks: one which can be used for activities with just one available resource unit and the other which defines the activities with more than one resource units.
3. To define the queues there are two types of blocks: one which can be used for activity with one available resource unit and the other which defines the queue for activities with more than one resource units.
4. There are two kinds of resources we want to optimize: first the human resources mean personnel of the emergency department and then the equipment such as patient beds.
5. And at last we consider that the simulation stops after 3000 events occurred.

So the model will be defined in software as what has shown in Figure 4.

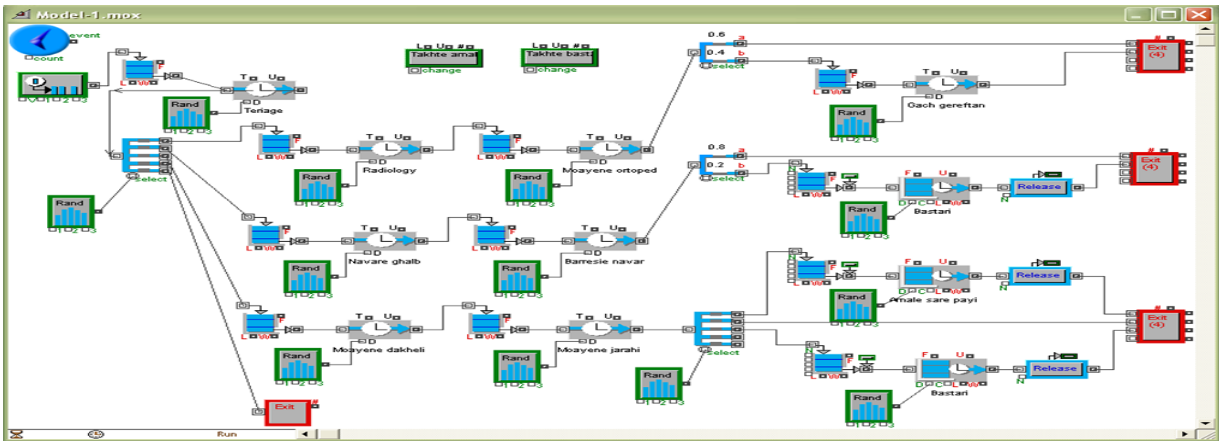

Figure 4. Model definition in the software

5. Model Simulation

After defining the model we run it. The wait times which seem to be high and so must be optimized is shown in Table3.

Table3. Simulation result before optimization

	Estimation	Estimation Range	
		Lower	upper
Examination in Triage			
Maximum wait	50	39	50
Care of heart patient			
Average wait	101	42	101
Maximum wait	355	218	355
Chalk spasm			
Average wait	95	54	95
Maximum wait	248	167	248
Care of damaged			
Average wait	151	96	151
Maximum wait	501	385	501
General surgery			
Maximum wait	65	49	65

6. Constraints

The constraint to employ personnel is the restricted budget. According to the different salaries of personnel as shown below we can define the constraints:

Table4. Salaries of personnel

Personnel	Cost (unit/day)
Specialist	30
General physician	24.6
Nurse	14.8
Assistant	6.5

And the constraint for equipment's is due to restricted budget and restricted space.

Table5. Constraint for equipment's

Equipment	Cost (unit)
Patient bed	500

To define the constraints two budget is supposed. One for current costs which consists of the personnel cost and the other budget consists of fixed costs by which bed costs are paid. So the constraints will be:
1) 30000*Var4 + 24600*Var5 + 14800*Var6 + 6500*Var7 ≤ 548000;
2) 500000*Var8 ≤ 100000;

7. Objective Function

Now since the waiting times in some parts are high, we consider the objective function to reduce the waiting time. By reducing the delay time, the output will be increased. So the function will be:

MaxProfit = Var0 + Var1 + Var2 + Var3;

In which Var0 refers to outputs from chalk spasm, Var1 refers to outputs from heart patients, Var2 refers to outputs from damaged patients, and Var3 refers to patients on who the general surgery has done.

8. Optimization

After defining the constraints and Objective function in “Evolutionary Optimizer” block we run the simulation. The results (amount of every resource after optimization) were as tables below:

Table6. Optimized resource allocation during daily shift

Daily shift			
Description	**Before Opt.**	**After Opt.**	**difference**
Specialist	1	1	-
General physician	4	5	1
Nurse	20	26	6
Assistant	15	20	5
Patient bed	20	25	5

Table7. Optimized resource allocation during daily shift

Nightly shift			
Description	**Before Opt.**	**After Opt.**	**difference**
Specialist	-	-	-
General physician	1	1	-
Nurse	6	7	1
Assistant	4	10	6
Patient bed	20	25	5

By new resource allocation, the wait times changes to amounts shown in Table8 (amounts are given in minutes):

Table8. Reduction of wait times after optimization

	Before Opt.	**After Opt.**	**Reduction**
Examination in Triage			
Maximum wait	50	33	17
Care of heart patient			
Average wait	101	71	30
Maximum wait	355	195	160
Chalk spasm			
Average wait	95	58	37
Maximum wait	248	148	100
Care of damaged			
Average wait	151	115	36
Maximum wait	501	317	184
General surgery			
Maximum wait	65	19	46

So by new resource allocation there would be a save of time about 610 minutes equal to 10 hours and 10 minutes daily.

9. Conclusion

Busy healthcare systems constantly provide new challenges to their managers and decision-makers due to high demands for service, high costs, limited budget, and healthcare resources. As a result, decision-makers are continuously studying efficacy and efficiency of existing healthcare systems, and must be able to evaluate the outcomes of any changes they make to these systems.

The article was looking to find out the best healthcare resources through simulation method. These resources can be analyzed according to simulation optimization modeling. Therefore the best healthcare resources can be chosen easily. Current approach shows the importance of management flexibility so they can change their decision to get to the best result. Simulation is one of the best tools which provide the best result compared to traditional methods. It provides the chance to involve the realistic factors of problem. It should be kept in mind which the first step is to decide applying different healthcare resources to improve the organization situation, then chose the best one with the help of simulation techniques.

This process enhances patient flow and reduces health care delivery costs. It also increases quality of service and patient satisfaction. Using such approach in this paper, we use simulation and optimization techniques to determine the best allocation of resources and its Applications in Hospital Emergency.

References

[1] SH. Jacobson, SN. Hall, JR. Swisher, Discrete-event simulation of health care systems. In: Hall RW, ed. Patient Flow: Reducing Delay in Healthcare Delivery. New York, NY: Springer; 211-52 **(2006)**.

[2] M.J. Côte, Patient flow and resource utilization in an outpatient clinic. Socioeconomic Planning Sciences 33 (3), 231–245 **(1999)**.

[3] J.R. Swisher, S.H. Jacobson, J.B. Jun, O. Balci, Modeling and analyzing a physician clinic environment using discrete-event (visual) simulation. Computers and Operations Research 28 (2), 105–125 **(2001)**.

[4] R.E. Blasak, W.S. Armel, D.W. Starks, M.C. Hayduk, The use of simulation to evaluate hospital operations between the emergency department and a medical telemetry unit. In: Proceedings of the 2003 Winter Simulation Conference, pp. 1887–1893.

[5] D. Sinreich, Y. Marmor, Emergency department operations: The basis for developing a simulation tool. IIE Transactions 37, 233–245 **(2005)**.

[6] H. Beaulieu, J.A. Ferland, B. Gendron, P. Michelon, A mathematical programming approach for scheduling physicians in the emergency room. Health Care Management Science 3 (3), 193–200 **(2000)**.

[7] S. Flessa, Where efficiency saves lives: A linear programing for the optimal allocation of health care resources in developing countries. Health Care Management Science 3 (3), 249–267 **(2000)**.

[8] V. De Angelis, G. Felici, P. Impelluso, Integrating simulation and optimization in health care center management. European Journal of Operational Research 150, 101–114 **(2003)**.

[9] F.F. Baesler, J.A. Sepúlveda, Multi-objective simulation optimization for a cancer treatment center. In: Proceedings of the 2001 Winter Simulation Conference, pp. 1405–1411.

[10] F.F. Baesler, H.E. Jahnsen, M. DaCosta, Emergency departments I: the use of simulation and design of experiments for estimating maximum capacity in an emergency room. In: Proceedings **(2003).**.